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ABSTRACT

The probability of obtaining a significant statistic, using the parametric analysis of covariance (ANCOVA) and the rank transform ANCOVA, was estimated for three conditions defined in terms of conditional distributions for two groups. The distributions were both normal, both skewed in the same direction but to different degrees, or both skewed to the same degree but in different directions. For each type of pair of conditional distributions both equal and unequal conditional means were studied. When the conditional distributions were skewed and the conditional means were unequal, both positive and negative correlations between height of the conditional mean function and degree or direction of skew were investigated. Sample size and strength of the covariate-dependent variable relationship were manipulated. The results were interpreted in terms of Type I error probabilities and power for testing two different null hypotheses: equality of two conditional mean functions, or equality of two conditional distributions. The results indicated the parametric ANCOVA should be used to test both hypotheses provided that the conditional distributions are normal or the correlation between the height of the conditional mean functions and the degree of skew is expected to be positive. (Author/DWH)

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Type I Error Probabilities and Power of the Rank and Parametric ANCOVA Procedures

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ABSTRACT

The probability of obtaining a significant statistic, using the parametric ANOCVA and the rank transform ANCOVA, was estimated for 3 conditions defined in terms of conditional distributions for two groups. The two conditional distributions were both normal, both skewed in the same direction but to different degrees, or both skewed to the same degree but in different directions. For each type of pair of conditional distributions both equal and unequal conditional means were studied. When the conditional distributions were skewed and the conditional means were unequal both positive and negative correlations between height of the conditional mean function and degree or direction of skew were investigated. Sample size and strength of the covariate-dependent variable relationship were manipulated. The results were interpreted in terms of Type I error probabilities and power for testing two different null hypotheses, equality of two conditional mean functions, or equality of two conditional distributions. The results indicated the parametric ANCOVA should be used to test both hypotheses provided that the conditional distributions are normal or the correlation between the height of the conditional mean functions and the degree ~~(or direction)~~ of skew is expected to be positive. If the correlation is expected to be negative then the choice of a statistical test depends on several factors and in many cases is fairly inconsequential.

Type I Error Probabilities and

Power of the Rank and Parametric ANCOVA Procedures

Most research designs for comparing the effectiveness of educational treatments yield data which can be analyzed by both parametric and nonparametric tests. To make a choice between the available procedures, it would be useful to have estimates of the actual (in contrast to the nominal) probability of a type I error and the actual power of the tests for a variety of distributions. Armed with this information, and considering the distribution in his or her study, the researcher can choose the most powerful test of the hypothesis he or she wants to test from among those tests that have actual alpha levels near the nominal alpha level. If a test has an actual alpha level near its nominal level, then we will say that the level of the test is preserved.

Recently there have been two investigations (Conover and Iman, 1980; Olejnik and Algina, 1983) of parametric and nonparametric ANCOVA which provided information of the kind described above. In these studies the nonparametric ANCOVA was a rank ANCOVA. In this procedure the dependent variable and covariate scores are transformed by ranking the original scores without regard to treatment groups. The transformed data are then analyzed using the parametric analysis. The test statistic is referred to the F distribution with the same degrees of freedom as the parametric case. Conover and Iman compared the two procedures by simulating data for the situation in which four treatments are to be compared. The conditional distribution for each group was normal, lognormal, exponential, uniform or Cauchy. In the null case the joint covariate-dependent variable distributions were the same for all four groups. The level of the rank procedure was preserved for all

five distributions. The level of the parametric procedure was preserved with the normal, exponential and uniform distributions, but was conservative with the lognormal and Cauchy distribution. In the non-null situation the covariate distributions were the same for the four groups but the conditional distributions differed in location for five of the six pairs of groups. The parametric ANCOVA was more powerful with the normal and uniform distributions but less powerful with the exponential, lognormal and Cauchy distributions. Olejnik and Algina conducted a simulation which focused on the two-group situation. Like Conover and Iman they studied the effects of nonnormal conditional distributions. However, the degree of conditional nonnormality was much less extreme than in the Conover-Iman study. In addition Olejnik and Algina investigated the effect of a type of heteroscedasticity in which the conditional variance increased as covariate scores increased, but the conditional variances were the same for both groups. In the null case the joint covariate-dependent variable distributions were the same for both groups, while in the non-null case only the conditional means differed across groups. Olejnik and Algina found that the level of both the rank and parametric ANCOVA was preserved with nonnormal, heteroscedastic, and nonnormal and heteroscedastic conditional distributions. They also found that when the conditional distributions differed in location the rank procedure can have a small power advantage if the conditional distributions are leptokurtic and the covariate-dependent variable correlation is small ($\rho = 3$ in their study). In addition the rank ANCOVA can have a substantial power advantage if the conditional distributions are leptokurtic and heteroscedastic, skewed and heteroscedastic, skewed and leptokurtic, or skewed, leptokurtic and heteroscedastic. The parametric ANCOVA can have a small power advantage if the conditional distribution is skewed and the covariate-dependent variable correlation is large ($\rho = .7$ in their study).

Although the Conover-Iman and Olejnik-Algina studies provide useful information for the researcher who needs to choose between the rank and parametric ANCOVA, they do not provide guidance in two important situations. In the first the researcher wants to test equality of conditional means but encounters conditional distributions that vary in skew across treatment groups. Here preservation of the level of the parametric ANCOVA is in question because the conditional distributions are nonnormal. Preservation of the level of the rank ANCOVA is in question because the researcher is only interested in detecting differences in conditional means, but the rank ANCOVA may be sensitive to between group differences in skew. In the second situation the researcher wants to test equality of conditional distributions and expects that the treatments will result in conditional distributions that differ across groups in mean and skew. With regard to preservation of level in the second situation we know from the work of Iman and Conover and Olejnik and Algina that if the joint covariate-dependent variable distribution is the same for both groups, then over a wide range of nonnormal conditional distributions both the rank and parametric ANCOVA tend to result in actual alpha levels near the nominal alpha level. (The major exception to this situation occurred in the Iman-Conover study in which the parametric ANCOVA was somewhat conservative with the lognormal and Cauchy distributions. In their study these distributions were extremely nonnormal.) Thus in the second situation the level of both procedures tends to be preserved. Therefore, in this study we are only interested in comparing the power of the two procedures in the second situation.

The context for the study is a randomized experiment comparing two groups. The shape of the conditional distributions is independent of the covariate scores and a covariate by treatment interaction does not exist. As a result conclusions about the utility of the procedures for testing

hypotheses about conditional means and conditional distributions also apply to testing the corresponding hypotheses about marginal means and marginal dependent variable distributions.

Method

In this study, data for a one-way design with two treatment groups, one dependent variable, and one covariate, were simulated. Three factors were considered: 1) sample size, 2) strength of the covariate-dependent variable correlation and 3) form of the conditional distribution. The levels of these factors were combined to form 40 conditions. The levels of the factors, data generation and condition combinations are described below.

Design

Sample Size. The study involved comparisons of two groups having equal sample sizes of either 20 or 40 observations each. A cell frequency of 20 was chosen as representative of small experiments, while the cell frequency of 40 was chosen to be representative of moderate sized experiments in the social sciences. Expense precluded simulating larger cell frequencies. In addition two group experiments with large cell frequencies seem to be infrequent in the social sciences.

Strength of the Covariate-Dependent Variable Correlation. Two levels of correlation were considered, .3 and .7. The correlation of .3 represents a relatively weak covariate-dependent variable relationship, while the correlation of .7 represents a relatively strong relationship. Together these probably cover the range of correlations that occur in applications of ANCOVA.

Form of the Conditional Distributions. The conditional distributions for the two treatment groups were either both skewed or both normal. For

the conditions involving skewed distributions, there were two cases. In Case A the degree of skewness was the same for both groups, but positive for one and negative for the other. Two levels of skewness were investigated $\pm.25$ and $\pm.75$. Frequency distributions based on a random sample of 10,000 observations from the distributions with skewness of .25, and .75 respectively are presented in Table 1. The levels of skewness were chosen to range from small to moderate. This is appropriate since distributions that are skewed in different directions and are extremely skewed seem unlikely to occur in practice. In Case B the direction of skewness was the same for both groups, but the degree was different. Two different combinations of skew were considered, .25, .50 and .25, .75. Based on the relative frequency distribution presented in Table 1, both combinations involve distributions with small to moderate degrees of skewness and involve relatively modest differences in skewness. Again these seem like the kinds of combinations that are most likely to occur in practice.

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Insert Table 1 Here

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Generation of the Data

The equation used to generate the dependent variable data was

$$Y = \rho X + E\sqrt{1-\rho^2} + C_j. \qquad (1)$$

For the case in which the conditional mean functions were the same for both groups, C_j was equal to zero for both groups. For the non-null case one of the C_j was equal to 0 and the other was set equal to .2, .4, .6, or .8 when the sample size was 20, (.15, .30, .45, and .60 when the sample size was 40) so that power curves could be generated for the various experimental conditions. In Case A it is possible to have either a positive or negative

correlation between C_j and the sign of the skew. In Case B it is possible to have either a positive or negative correlation between C_j and the degree of skew. Data conforming to both correlations were simulated for both Cases A and B.

For all experimental conditions X was distributed N(50,1). The coefficient ρ was set equal to .3 or .7 to simulate the two levels of strength of relationship presented earlier. The normally distributed covariate data were simulated by generating normal variables using the Statistical Analysis System (1982) normal function, and adding 50 to each. The normal conditional distributions were simulated again by generating normal random variates and assigning these values to E in (1). The non-normal conditional distributions were simulated by transforming a standard normal variable (z) to a new variable with mean zero, variance 1, and known skewness. The skewness was manipulated by choosing the appropriate coefficients in the formula

$$E = c + bz + cz^2 + dz^3$$

presented by Fleishman (1978).

Condition Combinations

For the non-normal conditional distributions the factors were combined in a 2 (sample size) x 2 (strength of relationship) x 4 (combination of skewness) x 2 (correlation between C_j and direction or degree of skew) design. Thus there were a total of 32 conditions involving non-normal conditional distributions. For each of these 32 conditions data were simulated both with C_2-C_1 equal to zero and with the four non-zero levels of C_2-C_1. However, when C_2-C_1 is zero the correlation between C_j and direction or degree of skew is not defined. Therefore, with the nonnormal conditional

distributions, when C_2-C_1 was equal to zero, there were really only 16 conditions with two replicates of equal condition. For the normal distributions the factors were combined in a 2 (sample size) x 2 (strength of relationship) design.

Results and Discussion

Type I Error Probabilities

One purpose of this study was to estimate the actual alpha levels of the parametric and rank ANCOVA procedures when they are used to test the null hypothesis of equality of conditional means of conditional distributions differing in direction of skew, or degree of skew. For each of the conditions studied, observations were simulated from two populations that had equal conditional means. The simulations were replicated 1000 times for each experimental condition, and the results were analyzed using the parametric and rank ANCOVA procedures, and nominal alpha levels of .01 and .05. For each test and alpha level the proportion of the 1000 replications resulting in a significant statistic provides an estimate of the actual alpha level. To identify those conditions for which a test did not preserve its level, a criterion interval of $\alpha \pm 2\sqrt{\alpha\,(1-\alpha)/1000}$ was used for nominal alpha levels of .01 and .05. For $\alpha = .01$ the interval is (.004, .016) and for $\alpha = .05$ the interval is (.036, .063).

Both procedures yielded estimated actual alpha levels that fell outside of the criterion interval described above. Table 2 identifies the conditions in which the estimated alpha levels for the parametric procedure were unacceptable, and Table 3 identifies the conditions in which the estimated alpha levels for the rank procedure were unacceptable. For each condition identified, the estimated actual alpha levels are reported.

Since conditions involving nonnormal conditional distributions were replicated twice, two estimated alpha levels are reported for each condition identified in Tables 2 and 3. The results in Table 2 suggest that while the parametric ANCOVA procedure did yield estimated alpha levels that were unacceptable, those levels were never far from the criterion interval limits. Further, estimated alpha levels were never outside the criterion interval for both replications. These findings suggest that the level of the parametric ANCOVA is preserved when conditional distributions differ in degree of skew or direction of skew at least for the levels of skew studied in this research.

As indicated in Table 3, when the conditional distributions are skewed $\pm.75$, and $\rho = .3$ the actual alpha levels are substantially above the upper limit of the criterion interval for both replications of each nominal alpha level. For the other conditions identified in Table 3 the estimated alpha level is above the upper limit of the criterion limit for only one of the replicates and this alpha level tends to be fairly close to the upper limit. Thus it appears that usually the levels of both tests are preserved. The exception is when the rank ANCOVA is employed with a relatively weak covariate-dependent variable correlation and with conditional distributions that are moderately skewed in opposite directions.

Although an investigation of the power of the rank ANCOVA to detect differences in skew was not a major objective of the study, the results also indicate that with the levels of skew investigated in the study, the rank ANCOVA is virtually powerless to detect differentially skewed conditional distributions that do not differ in conditional means.

Power Differences

A second purpose of the study was to compare the powers of the rank and parametric ANCOVA in two situations. In the first the researcher is

interested in detecting differences in conditional means but encounters conditional distributions that differ in skew across groups. In the second the researcher is interested in detecting differences in conditional distributions and expects that the treatments will result in conditional distributions that differ across groups in mean and skew. Again, for each of the experimental conditions observations were simulated from two populations with conditional mean functions that differed by a factor of .20, .40, .60, or .80 marginal standard deviation units, when sample sizes were 20 and 20. When sample sizes were 40 and 40, the conditional means functions differed by a factor of .15, .30, .45, or .60 standard deviation units. The 1000 replications for each condition were anlayzed using the parametric and rank ANCOVA procedures and nominal alpha levels of .01 and .05. For each test and nominal alpha level the proportion of the 1000 replications resulting in a significant statistic provides an estimate of the power of the test.

The results are reported in four tables. Each table reports the power of the parametric ANCOVA (p_p) and the power differences between the parametric and rank ANCOVA ($p_p - p_r$) for nominal $\alpha = .05$. The results for nominal $\alpha = .01$ are quite similar. For each condition in each table four power estimates and power difference estimates are reported, one for each of the four effect sizes investigated for that condition.

Case A. Table 4 reports $p_p - p_r$ for the normal conditional distributions and for the conditions with conditional distributions that differ in direction of skew and have a positive correlation between the sign of skew and C_j. The most obvious characteristic of the results is that with one exception the power differences are positive indicating that the parametric ANCOVA is more powerful for both the normal and nonnormal conditional

distributions. Since with one exception the power differences are all positive, the effects of the factors in the study do not have important implications for the choice of an analysis strategy. Nevertheless it may be interesting to note that for a particular sample size, strength of covariate-dependent variable correlation and effect size the power advantage for the parametric ANCOVA actually becomes larger as the conditional distributions become more nonnormal. To take the most extreme case, with $n_1 = n_2 = 40$ and $\rho = .3$, the largest power difference for the normal conditional distributions is .02 while the largest power difference for the $\pm$ .75 skewed conditional distributions is .235. Less extreme changes occur for the other combinations of sample size and covariate-dependent variable correlation. Nevertheless substantial changes do occur for each combination. It is also of interest that for a particular combination of sample size, covariate-dependent variable correlation, and effect size the power of the parametric ANCOVA is relatively unaffected by changes in the shape of the conditional distribution. (An exception to this generalization seems to occur for $n_1 = n_2 = 40$ on $\rho = 7$ in changing from the $\pm$ .25 to the $\pm$ .75 skewed conditional distributions.) Thus the effect of shape of the conditional distributions on power differences occurs because the power of the rank ANCOVA tends to decrease as the conditional distributions become more nonnormal.

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Insert Table 4 Here

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Table 5 presents p_p and $p_p - p_r$ for the conditions involving conditional distributions that differ in sign of skew and have a negative correlation between sign of skew and C_j. The power differences are inconsequential with

conditional distributions that are skewed $\pm.25$. It appears that with conditional distributions that are skewed $\pm.75$ some reasonably important power differences favoring the rank ANCOVA occur when $\rho = .3$ and $n_1 = n_2 = 20$ or $n_1 = n_2 = 40$, and when $\rho = .7$ and $n_1 = n_2 = 40$. The largest differences occur with $\rho = .3$ and $n_1 = n_2 = 40$. These are certainly practically important differences.

In interpreting these power differences it must be recalled that when the rank ANCOVA is used as a test of equality of conditional means the level of the test is not preserved when $\rho = .3$ for either $n_1 = n_2 = 20$ or $n_1 = n_2 = 40$ (see Table 3). Thus if the purpose of the analysis is to test for equality of conditional means the rank ANCOVA cannot be recommended in these conditions. It is recommended when $\rho = .7$ and $n_1 = n_2 = 40$ because the level of the test is preserved in this condition and enjoys a small power advantage. For the other conditions the choice between methods is relatively inconsequential. The levels of both tests are preserved when they are used to test equality of conditional distributions. Therefore in this situation the rank ANCOVA can be recommended when $\rho = .3$ and $n_1 = n_2 = 20$ or $n_1 = n_2 = 40$ and when $\rho = .7$ and $n_1 = n_2 = 40$. Again the choice is between methods of analysis inconsequential for the other conditions studied in this investigation. However, the results do suggest that the choice may not be inconsequential with larger sample sizes. For the conditional distributions that are skewed $\pm.25$, when $\rho = .3$ the power differences appear to change from favoring the parametric to favoring the rank ANCOVA when the sample size changes from $n_1 = n_2 = 20$ to $n_1 = n_2 = 40$. For the conditional distributions that are skewed $\pm.75$, when $\rho = .3$ the power differences favor the rank ANCOVA for both sample sizes but increase as sample sizes increase. Taken together these results suggest that with weak covariate-dependent variable

relationships and sample sizes larger than $n_1 = n_2 = 40$ the rank ANCOVA may have a practical power advantage even with conditional distributions that are slightly skewed in the opposite directions.

Case B. Table 6 presents p_p and $p_p - p_r$ for conditions involving conditional distributions that differ in degree of skew and have a positive correlation between C_j and degree of skew. The results indicate that the parametric ANCOVA is more powerful for all combinations of strength of the covariate-dependent variable relationship, sample size and magnitude of difference in skew. Thus the results suggest that when the conditional distributions differ in degree of skew and there is a positive correlation between C_j and degree of skew the parametric ANCOVA should be used.

Table 7 presents p_p and $p_p - p_r$ for the conditions involving conditional distributions that differ in degree of skew and have a negative correlation between C_j and degree of skew. For the most part the power differences are of little consequence. However, the parametric ANCOVA does appear to enjoy a small advantage for $\rho = .7$, $n_1 = n_2 = 20$ and both levels of difference in skew. The rank ANCOVA enjoys a power advantage of about the same magnitude with conditional distributions skewed .25: .75. $\rho = .3$ and $n_1 = n_2 = 40$. For a given level of difference in skewness and strength of the covariate-dependent variable relationship as the sample size increases the power differences in favor of the parametric ANCOVA tend to decrease and the power differences in favor of the rank ANCOVA tend to increase. This suggests that with larger sample sizes the rank ANCOVA may have a practically important power advantage over a range of strengths of covariate-dependent variable relationships and over a range of differences in degree of skew.

Conclusion

When testing the null hypothesis of equality of conditional means, the parametric and rank transform ANCOVA procedures usually preserve their levels when the populations differ in direction of skew, or degree of skew. The rank ANCOVA procedure, however, may be quite sensitive to moderate differences in direction of skew when the covariate-dependent variable correlation is weak. The levels of both tests are preserved, without exception, when they are used to test the equality of conditional distributions for populations differing in direction of skew or degree of skew.

For a positive correlation between sign or degree of skew and height of the conditional mean function, the parametric ANCOVA is consistently more powerful and is to be preferred both as a test of equality of conditional means and of conditional distributions. When the correlation between sign or degree of skew and height of the conditional mean function is negative, the choice of a test is much more complicated, and depends upon ρ, degree of difference in skew, sample sizes, and the hypothesis to be tested.

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Table 1

Relative Frequency Distribution for Observations of Three Skewed Random Variables[a]

Standard Deviations from the Mean	Degree of Skew		
	.25	.50	.75
$-\infty$,-3.0			
-3.0,-2.0	1.52		
-2.0,-1.0	14.34	17.05	18.20
-1.0, 0.0	36.16	36.91	37.82
0.0, 1.0	31.75	29.57	26.58
1.0, 2.0	13.40	13.25	13.34
2.0, 3.0	2.57	2.87	3.67
3.0, ∞	.26	.35	.39

a. Each frequency distribution is based on 10,000 observations.

Table 2

Conditions Which Resulted in an Actual Probability of a Type I Error Outside the Criterion Level: Parametric ANCOVA[a]

Skew	ρ	Sample Size	Nominal Alpha .01	Nominal Alpha .05
±.25	.3	20	.020,.011	
±.25	.7	40		.068,.051
±.75	.3	40		.054,.065
.25/.50	.7	40	.018,.004	
.25/.75	.3	20	.017,.010	
.25/.75	.3	40	.017,.011	
.25/.75	.7	40	.003,.009	

a. In all conditions identified in this table one of the two replications of the condition resulted in a Type I error probability outside the criterion interval.

Table 3

Conditions Which Resulted in an Actual Probability of a Type I Error Outside the Criterion Level: Rank ANCOVA

Skew	ρ	Sample Size	Nominal Alpha .01	Nominal Alpha .05
Normal	.7	40		.070[c]
±.75	.3	20	.022,.024[a]	.079,.018[a]
±.75	.3	40	.022,.040[a]	.086,.095[a]
±.75	.7	40	.019,.016[b]	.048,.066[b]
.25/.50	.3	40	.017,.011[b]	
.25/.75	.3	40	.022,.015[b]	

a. In both replications of this condition the actual probability of a Type I error was outside the criterion interval.

b. In one of the two replications of this condition the actual probability of a Type I error was outside the criterion interval.

c. There was only one replicate of this condition.

Table 4

Power of the Parametric ANCOVA (p_p) and Power Difference ($p_p - p_r$) between the Parametric and Rank ANCOVA[a]

Sample Size	ρ	Effect size	Conditional Distributions: Normal p_p	Normal $p_p - p_r$	±.25 p_p	±.25 $p_p - p_r$	±.75 p_p	±.75 $p_p - p_r$
20,20	3	.20	104[b]	-001	129	021	115	007
		.40	260	023	262	040	205	085
		.60	492	027	500	061	456	131
		.80	742	027	750	073	728	170
	.7	.20	158	019	144	027	101	021
		.40	393	037	407	056	358	090
		.60	732	064	734	061	751	144
		.80	929	029	927	029	957	053
40,40	.3	.15	102	001	100	011	095	050
		.30	300	017	274	062	280	158
		.45	565	022	544	086	550	232
		.60	780	022	821	101	814	235
	.7	.15	161	004	140	017	086	060
		.30	450	029	466	056	310	123
		.45	776	044	807	069	664	151
		.60	960	024	967	008	913	050

a. All results refer to the conditions with a positive correlation between sign of skew and C_j.

b. Decimal points are omitted.

Table 5

Power of the Parametric ANCOVA (p_p) and Power Difference ($p_p - p_r$) Between the Parametric and Rank ANCOVA: Case A[a]

Sample size	ρ	Effect size	Conditional Distributions ±.25 p_p	±.25 $p_p - p_r$	±.75 p_p	±.75 $p_p - p_3$
20,20	.3	.20	133	*002*	120	*-049*
		.40	214	*-001*	281	*-040*
		.60	491	*006*	492	*-043*
		.80	715	*027*	682	*-033*
	.7	.20	137	*000*	149	*-031*
		.40	395	*009*	408	*008*
		.60	705	*026*	693	*-007*
		.80	966	*026*	903	*-017*
40,40	.3	.15	101	*-019*	143	*-085*
		.30	277	*-027*	297	*-119*
		.45	545	*-001*	547	*-102*
		.60	768	*-017*	767	*-069*
	.7	.15	183	*-013*	137	*-043*
		.30	486	*017*	421	*-046*
		.45	873	*041*	740	*-025*
		.60	948	*009*	936	*002*

a. All results refer to the conditions with a negative correlation between sign of skew and C_j.

b. Decimal points are omitted.

Table 6

Power of the Parametric ANCOVA (p_p) and Power Differences ($p_p - p_r$) Between the Parametri. and Rank ANCOVA: Case B[a]

Sampe size	ρ	Effect size	Conditional Distributions .25, .50 p_p	.25, .50 $p_p - p_r$	.25, .75 p_p	.25, .75 $p_p - p_r$
20,20	.3	.20	088[b]	*007*	106	*015*
		.40	242	*031*	245	*029*
		.60	495	*040*	490	*040*
		.80	753	*058*	715	*048*
	.7	.20	124	*006*	140	*014*
		.40	406	*050*	415	*066*
		.60	727	*066*	723	*062*
		.80	924	*037*	932	*036*
40,40	.3	.15	097	*007*	109	*017*
		.30	268	*040*	298	*076*
		.45	543	*057*	542	*073*
		.60	787	*052*	822	*081*
	.7	.15	154	*026*	149	*021*
		.30	461	*059*	449	*068*
		.45	803	*041*	791	*069*
		.60	968	*021*	966	*039*

a. All results refer to the conditions with a positive correlation between C_j and degree of skew.

b. Decimal points are omitted.

Table 7

Power of the Parametric ANCOVA (p_p) and Power Differences ($p_p - p_r$) Between the Parametric and Rank ANCOVA: Case B[a]

Sample Size	ρ	Effect Size	Conditional Distributions .25, .50 p_p	.25, .50 $p_p - p_r$	.25, .75 p_p	.25, .75 $p_p - p_r$
20,20	.3	.20	109[b]	-003	107	-018
		.40	277	025	260	-013
		.60	486	010	475	-024
		.80	710	006	734	-012
	.7	.20	136	-002	146	005
		.40	415	051	382	061
		.60	696	040	733	047
		.80	908	035	915	033
40,40	.3	.15	103	-008	122	-026
		.30	275	-013	289	-059
		.45	524	000	542	-042
		.60	774	004	755	-036
	.7	.15	157	005	145	-014
		.30	440	009	450	011
		.45	798	031	788	020
		.60	957	005	955	007

a. All results refer to the conditions with a negative correlation between C_j and degree of skew.

b. Decimal points are omitted.